DOI:
10.1016/j.jsurg.2016.11.002

Document Version
Peer reviewed version

Citation for published version (APA):
Lovegrove, C., Ahmed, K., Novara, G., Guru, K., Mottrie, A., Challacombe, B., der Poel, H. V., Peabody, J., & Dasgupta, P. (2017). Modular Training for Robot-Assisted Radical Prostatectomy: Where to Begin? *Journal Of Surgical Education*, *74*(3), 486-494. https://doi.org/10.1016/j.jsurg.2016.11.002

Modular Training for Robot-Assisted Radical Prostatectomy: Where to Begin?☆,☆☆

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OBJECTIVE: Effective training is paramount for patient safety. Modular training entails advancing through surgical steps of increasing difficulty. This study aimed to construct a modular training pathway for use in robot-assisted radical prostatectomy (RARP). It aims to identify the sequence of procedural steps that are learnt before surgeons are able to perform a full procedure without an intervention from mentor.

DESIGN: This is a multi-institutional, prospective, observational, longitudinal study. We used a validated training tool (RARP Score). Data regarding surgeons' stage of training and progress were collected for analysis. A modular training pathway was constructed with consensus on the level of difficulty and evaluation of individual steps. We identified and recorded the sequence of steps performed by fellows during their learning curves.

SETTING AND PARTICIPANTS: We included 15 urology fellows from UK, Europe, and Australia.

RESULTS: A total of 15 surgeons were assessed by mentors in 425 RARP cases over 8 months (range: 7-79) across 15 international centers. There were substantial differences in the sequence of RARP steps according to the chronology of the procedure, difficulty level, and the order in which surgeons actually learned steps.

Steps were not attempted in chronological order. The greater the difficulty, the later the cohort first undertook the step ($p = 0.021$). The cohort undertook steps of difficulty level I at median case number 1. Steps of difficulty levels II, III, and IV showed more variation in median case number of the first attempt.

We recommend that, in the operating theater, steps be learned in order of increasing difficulty. A new modular training route has been designed. This incorporates the steps of RARP with the following order of priority: difficulty level > median case number of first attempt > most frequently undertaken in surgical training.

CONCLUSIONS: An evidence-based modular training pathway has been developed that facilitates a safe introduction to RARP for novice surgeons. (J Surg Ed ■:■■■-■■■.

KEY WORDS: modular training, RARP, safety, surgical training

ACGME COMPETENCIES: Patient Care, Medical Knowledge, Practice Based Learning and Improvement, Professionalism, Interpersonal Skills and Communication

INTRODUCTION

Increasing emphasis is placed on developing validated, feasible, and effective training and assessment methods to maximize patient safety while exploiting the benefits offered by robot-assisted surgery (RAS). Combined with reduced time available for training, the efficiency of training has become of increasing importance. This has resulted in the introduction

☆Development of an evidence-based modular training pathway for use by urology fellows in robot-assisted radical prostatectomy.

☆☆Financial support was received from the Department of Health via the National Institute for Health Research (NIHR) comprehensive Biomedical Research Centre award to Guy's and St Thomas' NHS Foundation Trust in partnership with King's College London and King's College Hospital NHS.

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of simulation and of modular training.[1] Modular training refers to progression through surgical steps of increasing difficulty, moving onto more advanced steps once competence has been attained in more straightforward ones.[2]

At present, there is a lack of procedure-specific guidance adopting a modular approach. Robot-assisted radical prostatectomy (RARP) is an indexed procedure within the specialty, worthy of evidence-based, well-developed, validated training and assessment methods. The technical and nontechnical skills required are imperative for the procedure, yet they can also be translated across to other specialties.

This study sought to construct a modular training pathway for RARP using principles that can be used to construct similar pathways in different operations and specialties. To do so we aimed to:

(1) Determine how surgeons progress through training for RARP at present.
(2) Determine the relationship between the difficulty of a procedural sub-step, when it is first undertaken in training, and the frequency with which it is performed.
(3) Construct a modular training pathway integrating the theory-based recommendations from the ERUS pilot study with evidence on how surgeons train in reality.

METHODS

Study Design and Participants

The study was conducted at an international, multi-institutional level with a prospective, observational, longitudinal design. The participants recruited were 15 urology fellows and their mentors from across Europe and Australia. There was no requirement for Institutional Review Board approval.

Process

Fellows progressed through the ERUS training curriculum using the 17-step RARP Assessment Score for training and progression assessment (Fig. 1).[3,4] This has previously been validated for use by expert urology surgeons and fellows. Fellows' technical proficiency was scored by their mentor each time they performed a step of RARP in the operating room. At the end of the study period, results were analyzed to examine patterns in training demonstrated by the fellows. Comparison was made to identify differences between recommendations from the literature and training pathways undertaken in practice.

Outcomes

Outcomes of interest were in the order of RARP steps as recommended by the literature according to the difficulty level, the total number of attempts of each step of RARP by the 15 fellows, and the case number at which each step was undertaken for the first time by fellows. Difficulty level was derived from the RARP Assessment Score where previously it had been designated by expert surgeons and undergone extensive content validation reaching a consensus. These parameters were used to formulate a modular training pathway using evidence from the literature and from the reality of the practice of the 15 fellows.

Statistical Analysis

SPSS version 22 was employed by this study (IBM Corp., Armonk, NY). Descriptive statistics were used to report results on patterns of training practice. Median case number and inter-D for when steps first attempted were noted. A $p < 0.05$ was taken as statistically significant.

RESULTS

Descriptive Statistics

After 425 RARP procedures, 15 urology fellows had attempted all steps of RARP (Table 1). All steps except steps 3 (laparoscopic adhesiolysis—86.7%), 7 (stitching and division of the dorsal venous complex—86.7%), 9 (posterior bladder neck transection—86.7%), and 17 (lymph node dissection—80.0%) had been done by all surgeons. The step performed most frequently was step 4: initiation of the console (372 cases), and the least practised was step 17: lymph node dissection (82 cases). The maximum number of attempts of a step of RARP by any 1 fellow was 79 (step 4: initiation of the console, step 2: pneumoperitoneum and port placement, and step 1: robot setup and patient positioning). The minimum number of attempts of a step by a fellow was 16 (step 13: apical dissection of the prostate, step 3: laparoscopic adhesiolysis).

Identification of Procedural Steps in a Chronological Manner

We used the steps of RARP as described in the RARP Assessment Score in chronological order within the procedure (Fig. 1).[4] Observation was made of the chronological order of steps of RARP, their difficulty (as designated in the literature), and the order in which the study population undertook them.

Relationship Between the Difficulty, First Attempt, and Frequency of Performance

On grouping steps of RARP according to difficulty level as rated by ERUS, it was apparent that there were differences between that and the chronological order of steps within a RARP procedure. Case number at which the cohort of fellows first attempted each step is reported in Table 2. At

Name:…………………… Date: …./…./ D'Amico risk:………….

erus eau SUB-PROCESS DEFINITIONS

cTNM Stage: T….N….M…. Patient's BMI: …..kg/m^2 Prostate Volume…..cc

STEP	DIFFICULTY	#	PROCESS	SUB-PROCESS DEFINITIONS	SCORING 1=Unacceptable 5= Excellent 0	1	2	3	4	5
Preparation of operative field	I	1	Robot set-up & patient positioning	Lithotomy position, angulation in Trendelenberg position, legs spread on adhesive covering						
	I	2	Pneumoperitoneum & port placement	If Veress needle used: appropriate insufflation (12-15mmHg) & placement of first trocar If Hasson technique is used: appropriate incision & placement of first trocar						
				Insert secondary ports under direct camera vision in correct position						
	II	3	Laparoscopic adhesiolysis *(if applicable)*	Lysis of abdominal adhesions						
	I	4	Initiation of console, ensuring robot is docked safely	Appropriate docking of the robot						
				Clean operative field by lysing pelvic adhesions up to sigmoid colon using 4th arm for mobilization & retraction						
Dissection of the bladder & prostate	II	5	Drop bladder from anterior wall	Correct opening of peritoneum						
				Good dissection in prevesical space of Retzius						
	II	6	Expose prostatic apex & endopelvic fascia *(varies)*	Remove fat over pubo-prostatic ligaments						
				Incise endopelvic fascia & mobilise prostate to reach membranous urethra						
				Incise puboprostatic ligaments (optional at this point)						
	II	7	Stitching & division of dorsal venous plexus *(varies)*	Suture Dorsal Venous Complex (if applicable)						
				Cut Dorsal Venous Plexus using cold instruments or stapler (if applicable)						
	II/III	8	Anterior bladder neck transection	Bladder traction by 4th arm/or traction by a stay suture on back of prostate						
				Dissect anterior bladder from prostate-vesical junction in correct plane, incise anterior bladder neck						
	III	9	Posterior bladder neck transection	Transect posterior bladder neck						
				Dissect & incise prostatovesical musculature						
	III	10	Seminal vesicle dissection	Identify seminal vesicles & vasa deferentia. Clip artery to vas deferentia						
				Dissect vasa deferentia & seminal vesicles						
	III	11	Posterior Dissection	Retract seminal vesicles anteriorly & cranially to expose Denonvilliers' fascia						
				Enter fascia in midline, mobilise prostate from rectum to develop rectal plane to reach apex						
	IV	12	Dissection of prostate pedicle & neurovascular bundle. Nerve preservation Y/N *(varies)*	Incise lateral prostatic fascia lateral to prostate & release neurovascular bundle from prostate capsule						
				Identify, clip & divide prostatic vascular pedicles						
				Use scissors & minimal traction to dissect neurovascular bundle						
				Dissection in right plane (intra-, inter-, extrafascial)						
				Avoid use of clips near apical stump						
	IV	13	Apical dissection of prostate *(varies)*	If not completed yet: incise puboprostatic ligaments & incise deep venous complex						
				Selective suturing of deep venous plexus (if applicable)						
				Examine apex of prostate to ensure that apical margins are avoided						
				Divide urethra						
Anastomosis & closure	III	14	Vesico-urethral anastomosis	Stabilisation of posterior sphincteric complex with a "Rocco" stitch (optional)						
				Modified Van Velthoven technique with a running suture (variable)						
				Anterior fixation & reconstruction (optional)						
	I	15	Inspection of abdomen	Haemostasis if necessary						
				Drain inserted & secured with suture (if applicable)						
				Hold specimen bag with grasper inserted through port (appropriate instructions/views for assistant)						
	I	16	Finalising	Remove instruments & ports from abdomen under direct vision & robot de-docked safely						
				Close skin layer						
	III	17	Lymph node dissection *(varies)*	Bilateral lymph node dissection						
				Extended or limited nodal dissection						

***Difficulty Definition**
I (lowest level of difficulty); IV (highest level of difficulty)

Score	0	1	2	3	4	5
Definition	NA	Unacceptable	Poor	Acceptable	Good	Excellent

FIGURE 1. RARP Assessment Score.[4]

least 1 fellow attempted each step on his or her first case of RARP in the study. The step with the latest first attempt by a surgeon was step 7: stitching and division of the dorsal venous complex.

Steps of RARP were examined for the median case number at which they were first attempted by the cohort of fellows (Fig. 2, Table 3). Steps with difficulty level I were all undertaken at a median case number 1. Steps of

TABLE 1. Descriptive Statistics After 426 RARP Procedures

Difficulty Level	Step # (of 17)	Step	# Surgeons Performed Step (%)	Total Attempts	Max Attempts by 1 Surgeon
I	1	Robot setup and patient positioning	15 (100%)	364	79
I	2	Pneumoperitoneum and port placement	15 (100%)	368	79
II	3	Laparoscopic adhesiolysis	13 (86.67%)	100	16
I	4	Initiation of console	15 (100%)	372	79
II	5	Drop bladder	15 (100%)	226	37
II	6	Expose prostatic apex and endopelvic fascia	15 (100%)	235	34
II	7	Stitching and division of DVC	13 (86.67%)	109	31
II/III	8	Anterior bladder neck transection	15 (100%)	170	29
III	9	Posterior bladder neck transection	13 (86.67%)	143	33
III	10	Seminal vesicle dissection	15 (100%)	170	27
III	11	Posterior dissection	15 (100%)	142	21
IV	12	Dissection of prostate pedicle and neurovascular bundle	15 (100%)	100	20
IV	13	Apical dissection of prostate	15 (100%)	106	16
III	14	Vesicourethral anastomosis	15 (100%)	181	32
I	15	Inspection of abdomen	15 (100%)	271	72
I	16	Finalizing	15 (100%)	328	75
III	17	Lymph node dissection	12 (80%)	82	25

DVC = dorsal venous complex.

difficulty levels II, III, and IV showed more variation in the median case number of the first attempt. A Kruskal-Wallis test showed that the greater the difficulty, the later the cohort undertook the step for the first time ($p = 0.021$).

Additionally, there was a statistically significant relationship between difficulty of step and total number of attempts by fellows ($\chi^2 = 11.08$, $p = 0.011$); more difficult steps were undertaken less frequently.

Construction of a Modular Training Pathway

There was a difference among the order of steps as ranked by chronology within the RARP operation, difficulty of procedural steps, and the order in which participants undertook their training.

To construct a modular training pathway, the steps of RARP were ordered using the aforementioned parameters with the following order of priority: difficulty level > median case number of first attempt > most frequently undertaken in surgical training. The proposed pathway is illustrated in Figure 3.

DISCUSSION

This study has developed a modular training pathway for RARP by integrating the theoretical basis of surgical training with how surgeons operate in practice. Using an international, multi-institutional, prospective, observational, longitudinal study design, a 5-step pathway was constructed incorporating 17 procedural sub-steps of RARP. The pathway accounts for the theoretical difficulty of each step, progressing from easier to more challenging steps. It also uses evidence on how 15 urology fellows progressed through 9 months training, as assessed by the RARP Assessment Score[4] (Fig. 1).

With the rise in RAS, it is imperative that surgical training adapt accordingly to exploit the benefits of the technology while protecting patient safety. Gone are the days of "see one, do one, teach one," instead there is greater recognition of the discrete intricacies required by both technical and nontechnical skills.[5-8] There is increasing evidence for the distinct training and assessment tools for the enhancement of each skill domain in surgeons.[9,10] Methods include didactic teaching through lectures or online materials and simulation training in a dry-lab, wet-lab, or virtual reality setting. This precedes progression to supervised operating in theater, eventually with the capacity to perform a full procedure to a competent standard.[11]

There exist several curricula for RAS, though many are in the early steps of development or validation.[12] Thus, there is a lack of standardization in surgical training and a need for valid, feasible, acceptable training that has educational impact.[3,13,14] Stolzenburg et al.[2] have developed a modular training pathway for laparoscopic extraperitoneal radical prostatectomy. The authors accounted for the difficulty of 12 individual steps. Their study investigated the effects on technical skill of using a modular training pathway grounded on difficulty alone.

This study sought to develop a pathway based both on technical difficulty and also on objectively observing how 15 fellows were guided by their mentors to participate in the 17 different steps of RARP over time. Variation was exhibited in the case number at which each procedural step was first attempted, and some steps demonstrated more variation

TABLE 2. Frequency for Case Number at Which First Attempt Was Undertaken

Step	Case # of First Attempt	Frequency	%
1	1	13	86.7
	3	1	6.7
	26	1	6.7
	Total	15	100.0
2	1	14	93.3
	26	1	6.7
	Total	15	100.0
3	1	9	69.2
	3	2	15.4
	18	1	7.7
	34	1	7.7
	Total	13	100.0
4	1	14	93.3
	18	1	6.7
	Total	15	100.0
5	1	8	53.3
	2	3	20.0
	7	1	6.7
	11	1	6.7
	14	1	6.7
	56	1	6.7
	Total	15	100.0
6	1	9	60.0
	2	1	6.7
	3	1	6.7
	7	1	6.7
	11	1	6.7
	14	1	6.7
	56	1	6.7
	Total	15	100.0
7	1	5	38.5
	3	1	7.7
	4	2	15.4
	11	1	7.7
	12	1	7.7
	14	1	7.7
	56	1	7.7
	59	1	7.7
	Total	13	100.0
8	1	7	46.7
	2	1	6.7
	3	1	6.7
	7	2	13.3
	8	1	6.7
	12	1	6.7
	18	1	6.7
	56	1	6.7
	Total	15	100.0
9	1	5	45.5
	2	2	18.2
	7	1	9.1
	13	1	9.1
	18	2	18.2
	Total	11	100.0
10	1	5	38.5
	2	1	7.7
	3	1	7.7
	4	2	15.4
	11	1	7.7
	13	1	7.7
	15	1	7.7
	29	1	7.7
	Total	13	100.0
11	1	5	33.3
	2	2	13.3
	3	1	6.7
	4	1	6.7
	10	1	6.7
	11	1	6.7
	13	1	6.7
	16	1	6.7
	29	1	6.7
	56	1	6.7
	Total	15	100.0
12	1	4	30.8
	2	2	15.4
	3	1	7.7
	7	1	7.7
	8	1	7.7
	10	1	7.7
	24	1	7.7
	54	1	7.7
	56	1	7.7
	Total	13	100.0
13	1	4	30.8
	2	3	23.1
	3	2	15.4
	6	1	7.7
	24	1	7.7
	48	1	7.7
	56	1	7.7
	Total	13	100.0
14	1	5	33.3
	2	3	20.0
	3	1	6.7
	4	1	6.7
	8	1	6.7
	11	1	6.7
	14	1	6.7
	17	1	6.7
	56	1	6.7
	Total	15	100.0
15	1	8	53.3
	2	1	6.7
	3	2	13.3
	4	1	6.7
	9	1	6.7
	13	1	6.7
	38	1	6.7
	Total	15	100.0
16	1	8	57.1
	2	2	14.3
	3	2	14.3
	13	1	7.1
	26	1	7.1
	Total	14	100.0
17	1	2	18.2
	4	3	27.3
	5	2	18.2
	6	1	9.1
	8	1	9.1
	16	1	9.1
	31	1	9.1
	Total	11	100.0

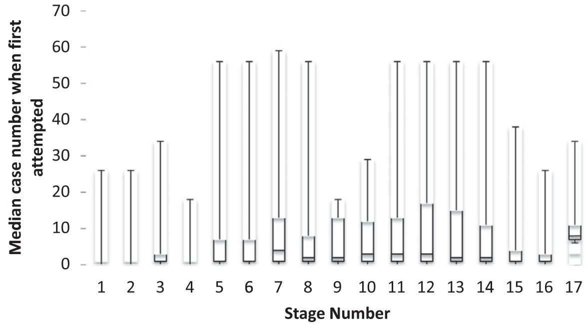

FIGURE 2. Median case number at which each step of RARP was first attempted by the cohort. Stage 1: robot setup and patient positioning, stage 2: pneumoperitoneum and port placement, stage 3: laparoscopic adhesiolysis, stage 4: initiation of the console ensuring that robot is docked safely, stage 5: drop bladder from anterior wall, stage 6: expose prostatic apex and endopelvic fascia, stage 7: stitching and division of dorsal venous plexus, stage 8: anterior bladder neck transection, stage 9: posterior bladder neck transection, stage 10: seminal vesicle dissection, stage 11: posterior dissection, stage 12: dissection of prostate pedicle and neurovascular bundle, stage 13: apical dissection of prostate, stage 14: vesicourethral anastomosis, stage 15: inspection of abdomen, stage 16: finalizing, and stage 17: lymph node dissection.

than others (Table 2). Step 2 (pneumoperitoneum & port placement) was undertaken in the first assessed RARP case in 14 of 15 fellows (86.7%). Conversely, step 11 (posterior dissection) was originally attempted in the first case by 33.34% of fellows, case 2 by 13.34% and cases 3, 4, 10, 11, 13, 16, 29, and 56 by 6.7% each. The trend for step 11 to be initially endeavored later in training and exhibiting a greater spread when it was first undertaken may be a reflection of it being of greater difficulty than step 2 (difficulty III vs. difficulty I). There was a statistically significant relationship demonstrating that more difficult steps were first undertaken later in the study ($p = 0.021$). This is illustrated in Figure 2. Here, mentors have the role to advise fellows on their participation in surgery according to the competence exhibited to date. As more challenging technical skill is required for step 11, it is logical that it be attempted later in training than step 2.[15]

The data are at risk of bias, as not all steps of the operation were performed the same number of times. To account for this, the training pathway designed also incorporates the frequency with which the fellows did each step. Steps done more frequently were prioritized for earlier in the pathway over those done more infrequently. The steps done less frequently were likely to have had a higher level of difficulty ($p = 0.011$), a reason for mentors to postpone fellows from their first attempt until later in their surgical education. Furthermore, experience and dexterity gained from easier steps is of use when completing more complicated tasks. Thus, more frequent performance of these steps does not necessarily imply that harder steps are being neglected.

This modular pathway accounts for progression through the learning curve from easier steps to those requiring additional technical competence and experience. In 1936, T.P Wright described the practical application of learning curve theory to aeronautical manufacturing in the United States.[16] By comparing fellows' learning with productivity, he identified a relationship with reduced production cost. In surgery, the principle assumes that greater training time and larger caseloads translate to improved surgical skill, eventually reaching a level of "competence" with improved outcomes. At this point, the learning curve plateaus, indicating consistency in surgical practice. This is especially important when considering the steps in an operation that are most likely to compromise patient safety; usually the most technically challenging steps.[17] The approach

TABLE 3. Median Case Number of First Attempt for Each Step or RARP

Step	Difficulty	Minimum Case # of First Attempt	Maximum Case # of First Attempt	Median Case # of First Attempt	IQR
1	I	1	26	1	(1-1)
2	I	1	26	1	(1-1)
3	II	1	34	1	(1-3)
4	I	1	18	1	(1-1)
5	II	1	56	1	(1-7)
6	II	1	56	1	(1-7)
7	II	1	59	4	(1-13)
8	II/III	1	56	2	(1-8)
9	III	1	18	2	(1-13)
10	III	1	29	3	(1-12)
11	III	1	56	3	(1-13)
12	IV	1	56	3	(1-17)
13	IV	1	56	2	(1–15)
14	III	1	56	2	(1-11)
15	I	1	38	1	(1-4)
16	I	1	26	1	(1-3)
17	III	1	31	5	(4-8)

IQR, interquartile range.

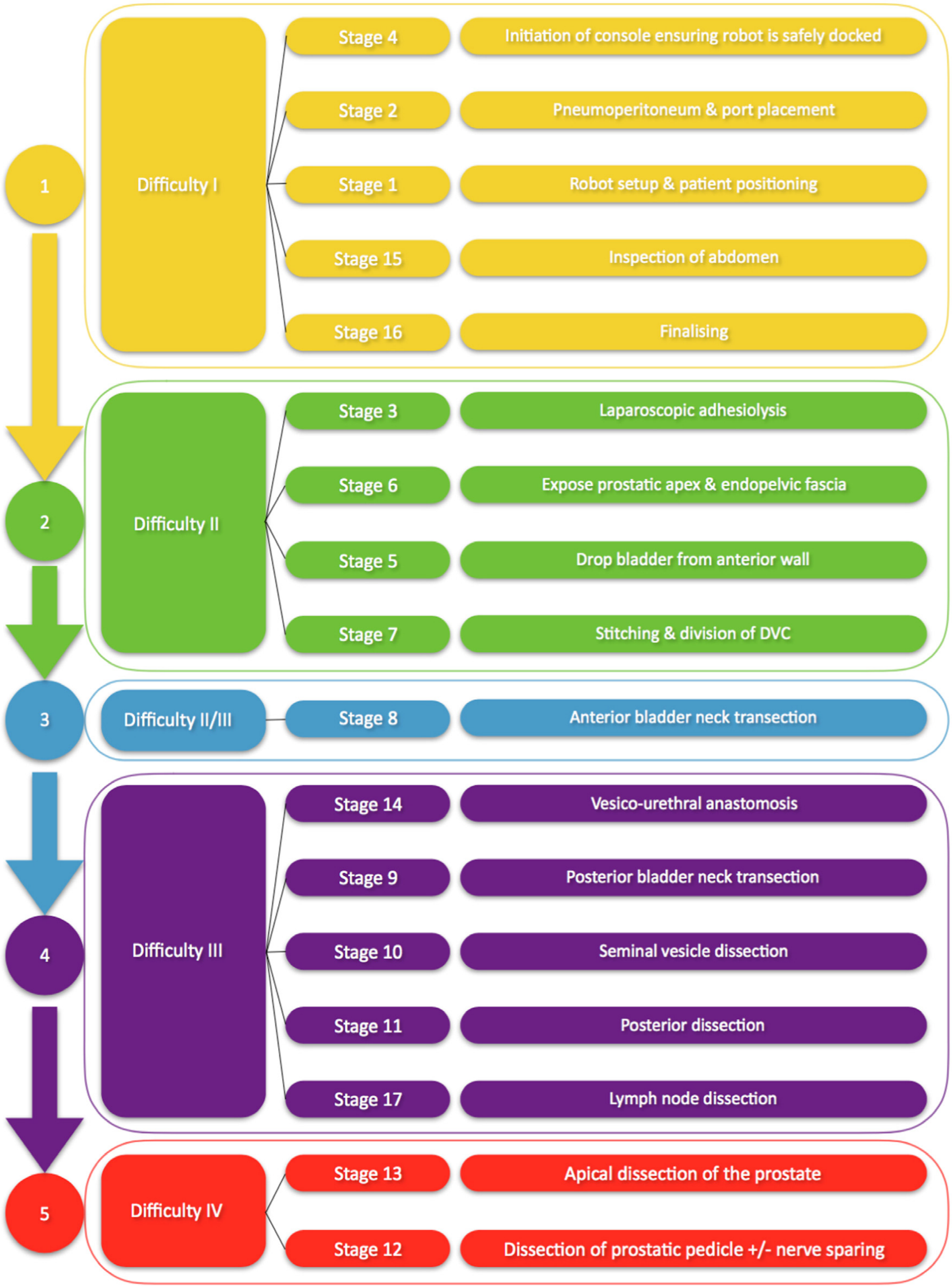

FIGURE 3. Recommended RARP modular training pathway.

incorporates "mastery learning" where training is based on achieving a defined standard in knowledge and skills as opposed to a specific time period.[18] Proficiency, rather than time-based learning, has been demonstrated to reduce complications in other specialties.[19] It remains to be seen whether the methodology may increase the efficiency of surgical training though it holds promise for improving quality of patient care.

A modular approach to learning allows more senior surgeons to intervene when necessary in an operation, averting technical error and maintaining a safe, acceptable operative time.[2] Moreover, the training pathway enables practice to be undertaken in a range of settings in an era where fellows frequently operate under the supervision of a range of seniors often at a number of hospitals with variability in case complexity. One operation can be divided up between surgeons and still have a beneficial effect on the development of a fellow's technical skills while preserving patient safety as far as possible.

Knowledge of when fellows can be expected to consistently carry out these difficult steps with proficiency is important in surgical education to avoid poor outcomes. This study exhibits numerous strengths. Its prospective, longitudinal design observing the practice of 15 fellows and their mentors over 9 months and 426 RARP procedures enables a thorough analysis of trends in how surgeons train in reality. It uses a validated RARP Assessment Score to follow fellows.[4] The extensive content validation performed previously ensured that the important sub-steps of RARP were included in training surgeons. Systematic development of the modular pathway has been undertaken, incorporating the theories behind how to train surgeons and how this is undertaken in practice. The stepwise approach of increasing difficulty guards against surgeons attempting steps which are too complex, promoting the acquisition of competent operating and patient safety.

Limitations associated with the study include the small cohort of only 15 fellows; ideally a greater sample size would be used to increase the validity of findings and refine the modular pathway developed. Steps of RARP first undertaken were subject to numerous variables including patient details (step of disease, existing comorbidities), caseload at the center, and competition with other fellows for operative practice as a consequence of reduced training opportunities.[20]

Future work should focus on integrating this modular pathway into a curriculum with didactic and simulated elements in addition to nontechnical skills training. Construct validity, acceptability, feasibility, and educational impact should be assessed through follow-up, surveying fellows, and assessment of patient outcomes.

CONCLUSION

An evidence-based modular training pathway was constructed. It displays content validity and promotes the integration of theory-based training models with the practicalities of surgical training. Progression from easier steps of RARP to those that are more difficult encourages the development of technical skill in preparation for more complex tasks. Further work is required to integrate this into a full curriculum for use in RARP and validate it for use in clinical practice.

DISCLOSURES

P.D. acknowledges financial support from the *National Institute for Health Research* (NIHR) *Biomedical Research Center* based at *Guy's* and *St Thomas' NHS Foundation Trust* and *King's College London*. The views expressed are those of the author(s) and not necessarily those of the NHS, the NIHR, or the *Department of Health*. P.D. also acknowledges the support of the *MRC Center for Transplantation, London Deanery, London School of Surgery, GSTT Charity, EU, Vattikuti Foundation* and *Olympus*. P.D., K.A. acknowledges funding for the SIMULATE project from the *Urology Foundation* (TUF) and the BAUS. CL, KA, and PD acknowledge educational funding from the *Royal College of Surgeons of England*.

There are no further disclosures from Giacomo Novara, Khurshid Guru, Alex Mottrie, Ben Challacombe, Henk Van der Poel, nor James Peabody.

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